# The Deep Space 4/Champollion Mission

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## 1. Introduction

The Deep Space 4 (DS4) mission with the Champollion lander is being developed in collaboration with the New Millennium Program at JPL and is on target for a Phase C/D start in October 1998. The goals of the New Millennium Program are to qualify advanced technologies for use on future NASA missions and to perform meaningful science with the new technology. The DS4/Champollion spacecraft would perform the first landing of scientific instruments on the surface of a comet, and demonstrate technologies for collecting and returning extraterrestrial samples to a mother spacecraft and, thence, to Earth laboratories. Since comets contain a cosmo-chemical record of the conditions and composition of the primordial solar nebula at the time of the formation of the planetary system. The *in situ* study and return of cometary samples are thus among the highest priority goals of the planetary exploration program.

## 2. DS4/Champollion Mission Description

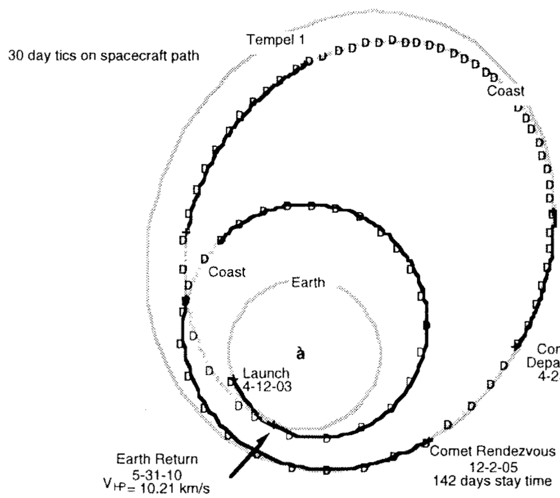


***Figure 1: Interplanetary Trajectory***

The DS4/Champollion mission plan (see Figure 1) is to launch in April-May, 2003 on a Delta 7925 launch vehicle, using a 11 kW solar electric powered (SEP) carrier spacecraft to take DS4/Champollion to a rendezvous with periodic Comet Tempel 1. Flight time with the SEP stage is 2.7 years, considerably shorter than typical ballistic trajectories. Rendezvous occurs post-perihelion at about 2.5 AU from the Sun. After a series of slow flybys, the spacecraft will be placed in a low orbit around the nucleus of P/Tempel 1. DS4/Champollion would plan to spend nearly 5 months at the comet in order to map completely the nucleus surface at high resolution, prior to deploying the Lander spacecraft. In addition, radio tracking data will be used to determine the nucleus mass and gravity harmonics, and will be combined with imaging data to estimate the bulk density of the cometary nucleus.

The 3-axis stabilized Champollion Lander will slowly descend to the comet's surface using autonomous navigation, nulling out the lander velocity just before contact with the nucleus. At touchdown an explosive, deployable harpoon will anchor the spacecraft to the surface to permit drilling operations and other relevant scientific measurements. Operations on the nucleus surface are expected to last 3 1/2 days. Scientists on the ground will update sequences based on quick-look analyses of earlier measurements.

| PI/Organization | Name | Type |
|---|---|---|
| Yelle/Boston University (US) | CIRCLE | Near field camera, microscope, IR spectrometer |
| Bibring/IAS (France) | ISIS | Panoramic camera |
| Mahaffy/GSFC (US) | CHARGE | Gas chromatograph / mass spectrometer |
| Ahrens/CalTech (US) | CPPP | Physical properties probes |
| Total Science Mass: 18 kg<br>(Includes sample acquisition / transport) | | |

***Table 1: Selected Lander Payload***

The current Champollion payload is shown in Table 1. It includes panoramic and near-field cameras, a combined infrared spectrometer/microscope for examining collected samples, a one-meter drill for obtaining cometary samples at depth, a gas chromatograph/mass spectrometer for analyzing collected surface and sub-surface samples, and a physical properties experiment to measure the strength, density, temperature, conductivity and other properties of the nucleus surface. The payload may also include a gamma ray spectrometer for bulk elemental analysis of the near-surface materials.

The Champollion Lander will then collect a sub-surface sample, detach itself from the anchor, and take off, leaving the lower portion of the spacecraft and most scientific instruments on the comet. The Lander will rendezvous with the Cruise Stage and transfer the sample to the Re-entry Capsule. The sample will be returned to Earth for analysis in terrestrial laboratories. Flight time back to Earth is 4.2 years, delivering the sample in June, 2010. The passively cooled sample would be enclosed in a direct entry capsule that would decelerate in the Earth's atmosphere and then parachute safely to the surface.

An option currently being studied is to use a chemical propulsion stage rather than SEP for deep space maneuvers to target the sample return for Earth entry. This would permit a longer duration stay at the comet during which additional science data could be obtained, and may have substantial mass and/or operational advantages.

## 3. DS4/Champollion Spacecraft Description

### 3.1 Cruise Stage

The primary characteristics of the DS4/Champollion Cruise Stage spacecraft are shown in Figure 2. It uses solar electric powered thruster technology, to be qualified on the first New Millennium mission spacecraft, Deep Space 1 (to be launched in July, 1998). This enables a much shorter flight time to the comet than typical chemical propulsion systems. The cruise stage provides the telecom link to Earth while the lander is on the surface of Comet Tempel 1Further specifications of the cruise stage are provided in Table 2. Notice that the configuration in cruise is different on the outgoing leg (Figure 2a) from that on the Earth return leg (Figure 2b). The difference lies in the orientation of the attached lander with respect to the carrier stage bus.

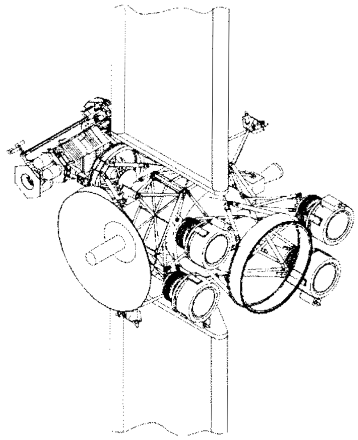

***Figure 2a: Cruise Stage Configuration <u>to</u> Comet***

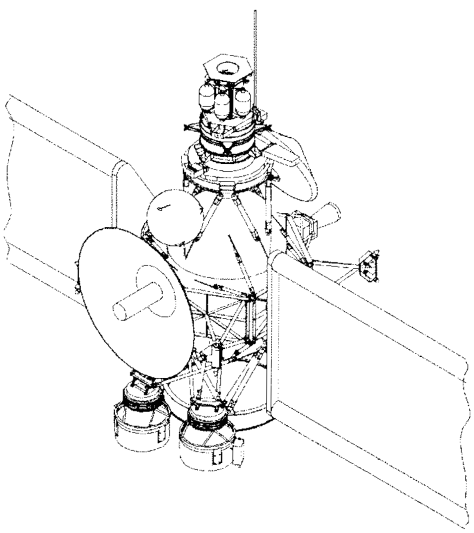

***Figure 2b: Cruise Configuration <u>from</u> Comet***

| | |
|---|---|
| Propulsion | Solar electric propulsion: 4 thrusters,<br>410 kg xenon |
| Attitude Control | Hydrazine: 12 @ 1.0 N thrusters,<br>29 kg hydrazine<br><br>Sensors: op-nav<br>camera, star scanners, sun sensors, IMU |
| Telecom | X-band: 0.9 meter HGA, 20 W power amplifier<br><br>Link to Earth:<br>UHF link to lander |
| Power | 2-wing solar arrays: 11k W @ 1.0 AU<br>40 Amp-hr Li-ion secondary battery |
| Mechanical/Thermal | Integrated Avionics System: Electronic boards, structure and cabling. Passive thermal control |

***Table 2: Specifications of Cruise Stage***

### 3.2 Lander

The 120 kg Champollion Lander spacecraft is shown in Figure 3. It carries the scientific payload, descent and anchoring subsystems, central computer and data storage. The Lander uses onboard autonomy and precision guidance to maneuver to a pre-selected site on the nucleus surface and to touch down at a velocity of 0.25 m/sec or less. A 3-meter harpoon deploys explosively to anchor the Lander to the nucleus surface so that drilling operations may proceed in the low gravity environment. Surface physical properties sensors are deployed on two outrigger arms. Figures 4a and 4b show the lander in its deployed state and on lift-off from the comet, respectively. A concept for docking of the lander with the orbiter is shown in Figure 5.

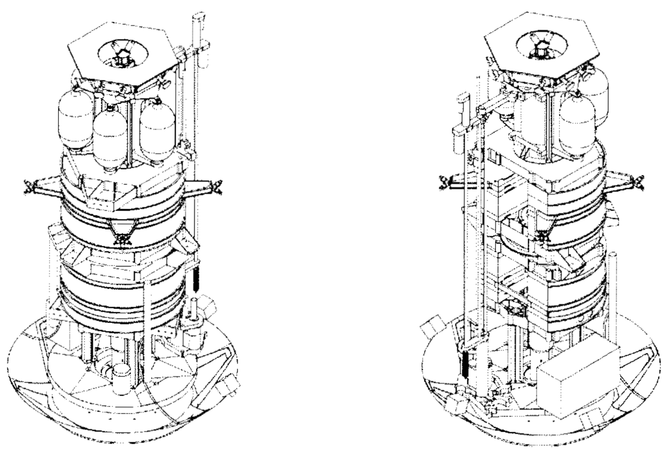

***Figure 3: Champollion Lander Configuration***

| | |
|---|---|
| Propulsion | Cold Gas: 16 @ 1.0 N thrusters, 4.0 kg $N_2$ |
| Attitude Control | Sensors: IMU |
| Telecom | UHF link to Cruise Stage: 90 kbytes/sec |
| Power | Primary batteries: 4,500 W-hv |
| Avionics | X-2000 technology - TBD |
| Landing | Precision guidance and landing system: radar altimeter. |
| Anchoring | Central telescoping spike: 3 m anchor, 0.5 m diameter flare, 0.75 m diameter snowshoe |
| Mechanical Thermal | Integrated Avionics System: Electronics, instruments, structure & cabling. Passive thermal control |

***Table 3: Champollion Lander Specifications***

### 3.3 Earth Re-Entry Capsule

The Champollion Re-entry Capsule (ERC) will hold up to 45 $cm^3$ of cometary material extracted from one or more drill holes on the nucleus surface, to a depth of 1-meter. The entire sample is to be carried in a single container. Mechanisms and multiple containers are being studied to segregate samples collected at different depths or from different drill holes, so as to provide additional data on vertical and horizontal heterogeneity. The capsule is designed to maintain the collected sample at a cryogenic temperature of 130-150 K during the return cruise and re-entry periods. Sensors in the capsule will maintain a record of its temperature and shock history during the return to Earth.

The re-entry capsule will be targeted to a designated recovery site, probably in the western United States, and will be recovered within 1-6 hours after landing. The sample will be maintained in a cryogenic state and will be flown to the appropriate NASA sample analysis facility where it will be examined and analyzed under carefully controlled conditions. A preliminary concept for the ERC is shown in Figure 6 and some design details are given in Table 4.

| | |
|---|---|
| Entry & Recovery | Aeroshell, parachute, GPS receiver, UHF transmitter |
| Thermal | Entry thermal protection system: PICA ablator. Passive cryogenic environmental control: dewar with phase change material |

***Table 4: ERC Design Details***

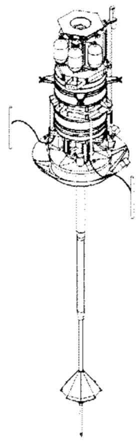

*Figure 4a: Lander with Anchor and CPPP Deployed*

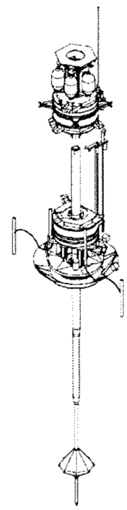

*Figure 4b: Lander on Liftoff from Comet*

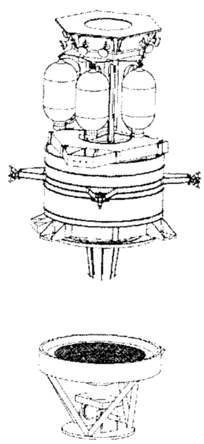

*Figure 5: Docking*

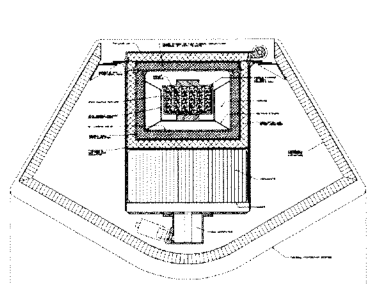

*Figure 6: Earth Re-entry Capsule (ERC) Configuration*

## 4. Technology Demonstrations

As stated above, a primary objective of DS4 is to demonstrate the utility of new technologies that are now judged to be beneficial to future science return missions. These technologies appear throughout this mission and include:

1. Advanced, lightweight solar arrays
2. High-performance, multi-engine ion electric propulsion
3. Autonomous precision guidance and control for landing
4. Anchoring systems for comets and other small bodies
5. Subsurface sample acquisition and transfer to instruments
6. Integrated high-performance electronics and software architecture
7. UHF transceiver for communications between lander and carrier
8. Small transponding modem
9. Automated orbital rendezvous and docking

## 5. Conclusions

The Deep Space 4 / Champollion mission is being developed in conjunction with many programs, each of which seek to address the low cost aspect of planetary exploration. In both its technology demonstration objectives as well as its science data gathering, it will be a significant step forward in our initial, *in situ* exploration of small bodies in the solar system.

## 6. Acknowledgments

The authors recognize the contributions of all members of the project team in developing this concept. The work described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.